Groundwater High-Resolution Site Characterization (HRSC)

United States Environmental Protection Agency

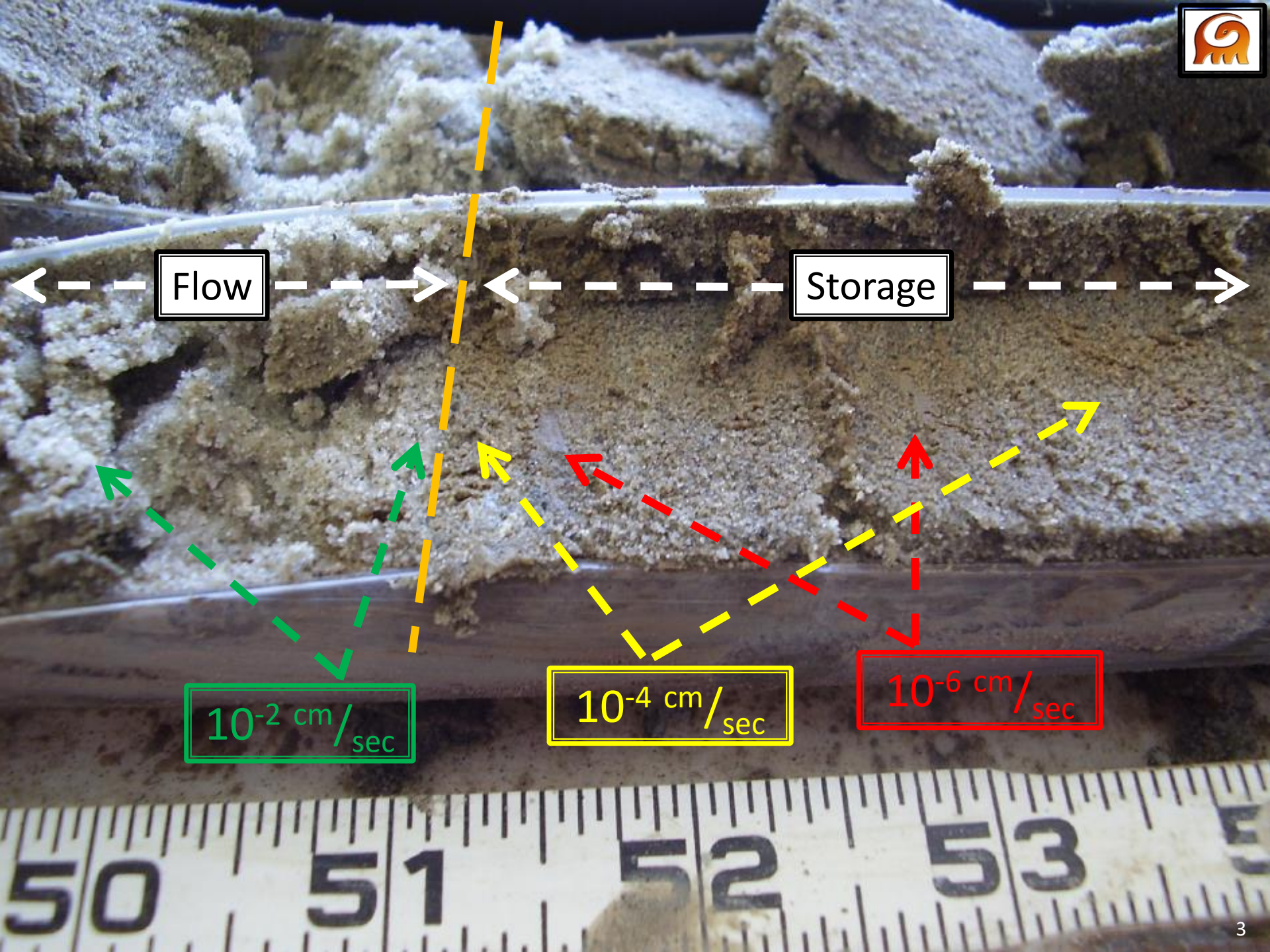
Ed Gilbert, CPG
Office of Superfund Remediation and Technology Innovation

47th Annual ENVIRONMENTAL SHOW OF THE SOUTH
Chattanooga, TN, May 16-18, 2018

Presentation Outline

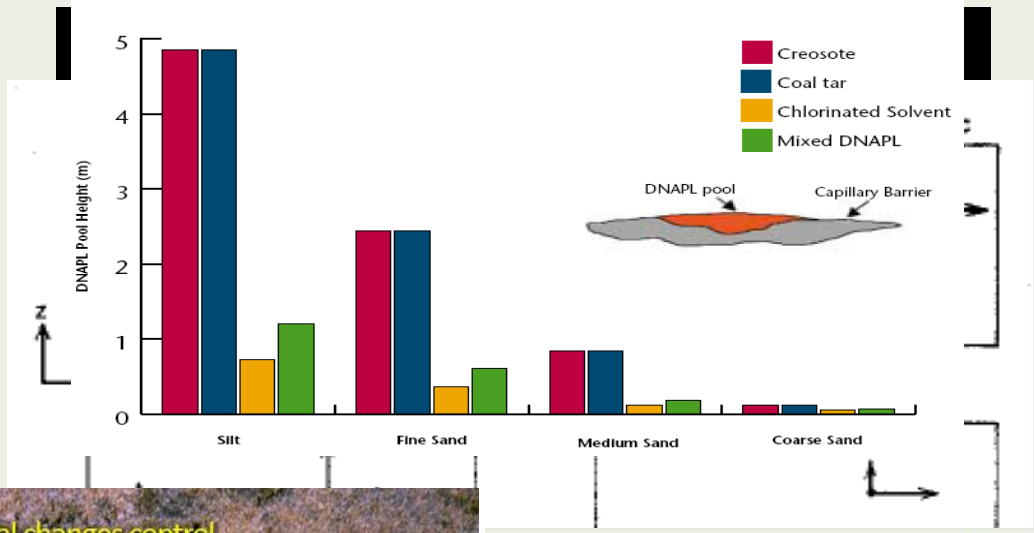
- Offer brief hydrogeologic context
- Explain need for High-Resolution Site Characterization (HRSC)
- Define HRSC
- Review strategy and tools for groundwater HRSC

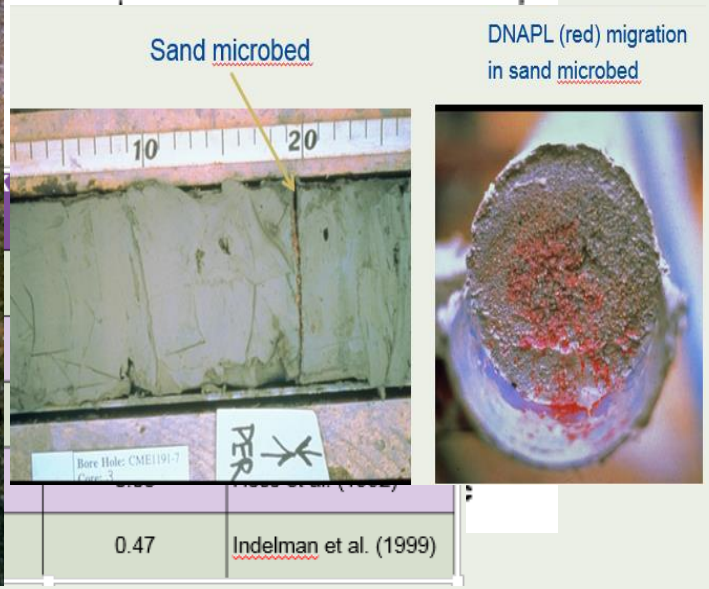
- DISCLAIMER:
  - » Information in this presentation represents the views of the presenter and has not received formal U.S. EPA peer review.
  - » This information does not necessarily reflect the views of U.S. EPA, and no official endorsement should be inferred.
  - » The information is not intended, nor can it be relied upon, to create any rights enforceable by any party in litigation with the United States or any other party.
  - » Use or mention of trade names does not constitute an endorsement or recommendation for use


Flow
Storage
10-2 cm/sec
10-4 cm/sec
10-6 cm/sec
50
51
52
53

Challenges

- Heterogeneity, anisotropy
- Contaminant phase behavior
  - NAPL
    - Density
    - Viscosity
    - Mobility
    - Dissolution
  - Gas
  - Aqueous
  - Sorbed





Geologic heterogeneity controls mass distribution

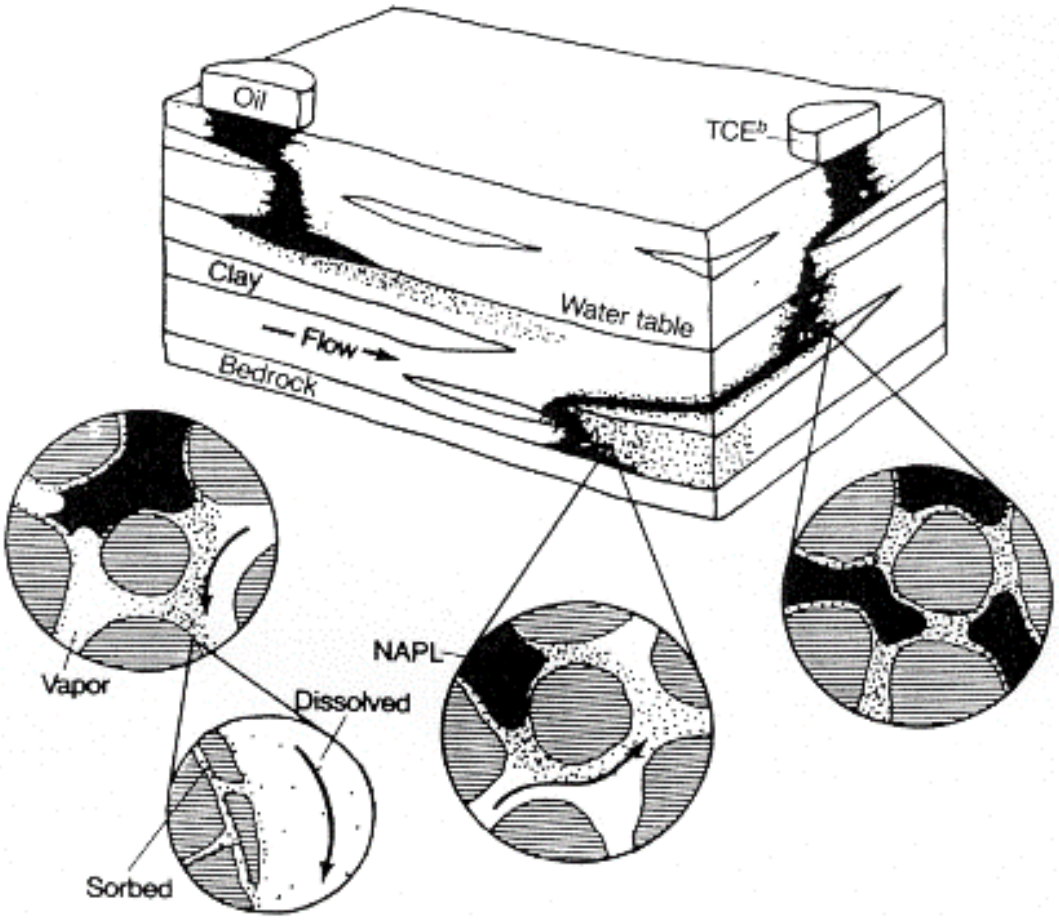
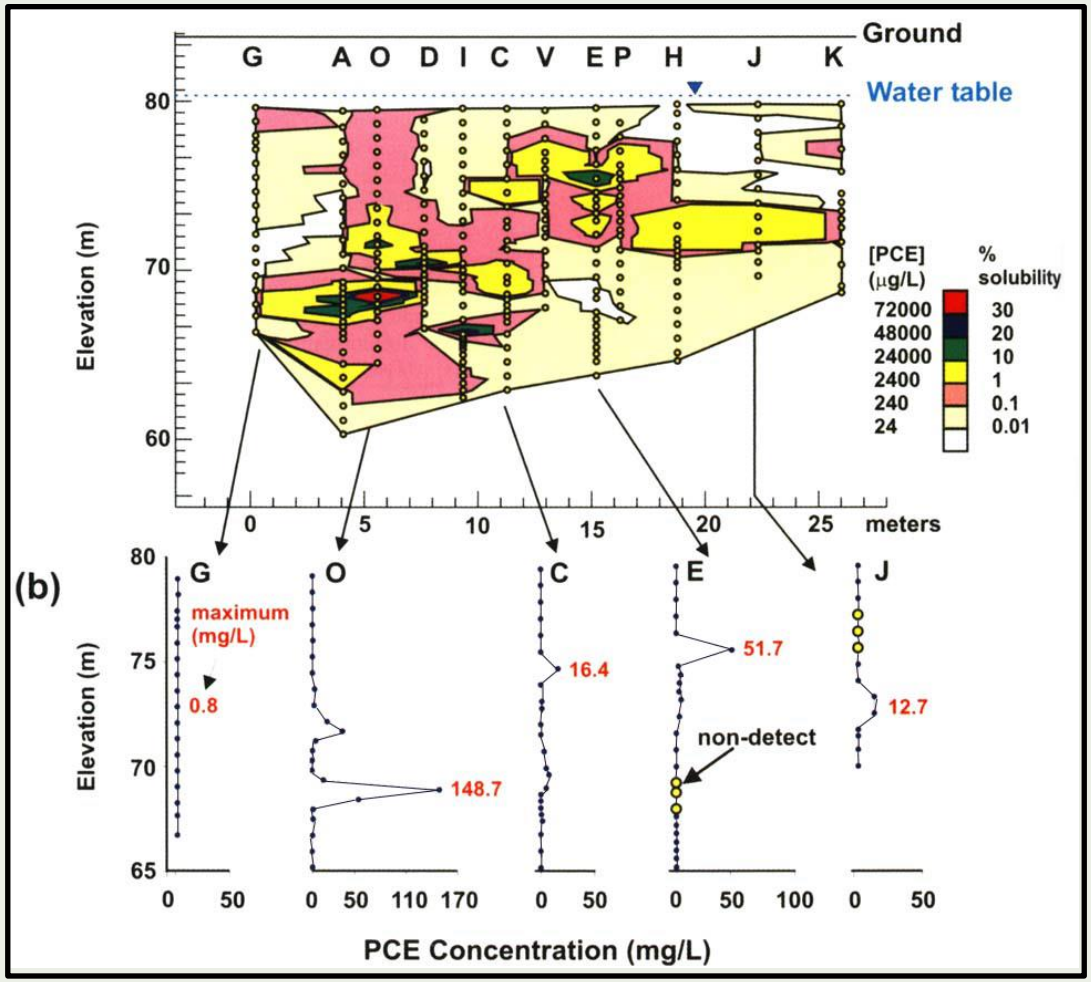


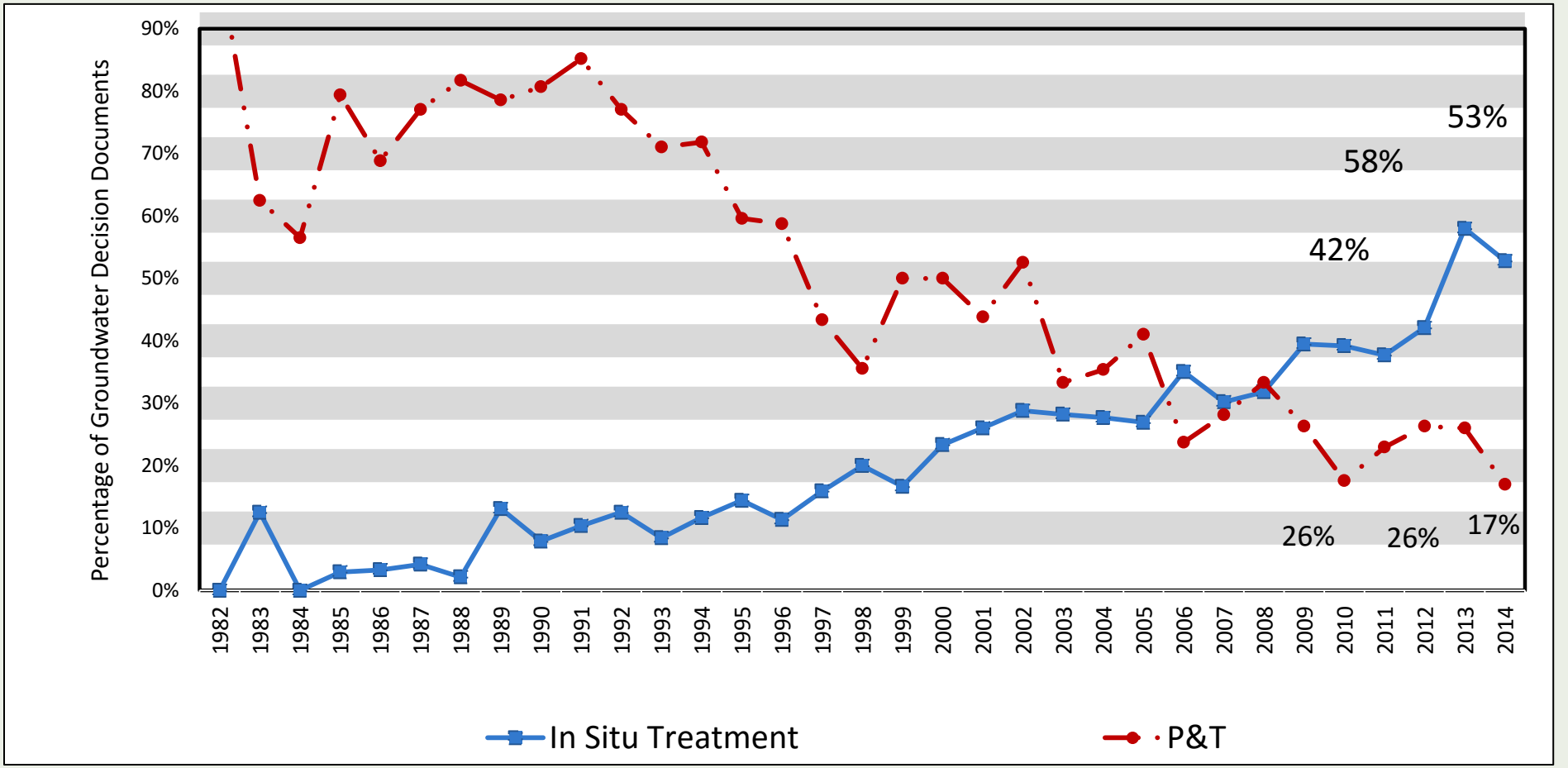
Figure 2.1 Schematic illustration of a DNAPL and a LNAPL in a porous medium, showing geologic and pore scales. A low-permeability clay layer deflects the DNAPL. DNAPL dissolution causes a plume (from Mackay and Cherry, 1989).

Geologic heterogeneity controls mass distribution



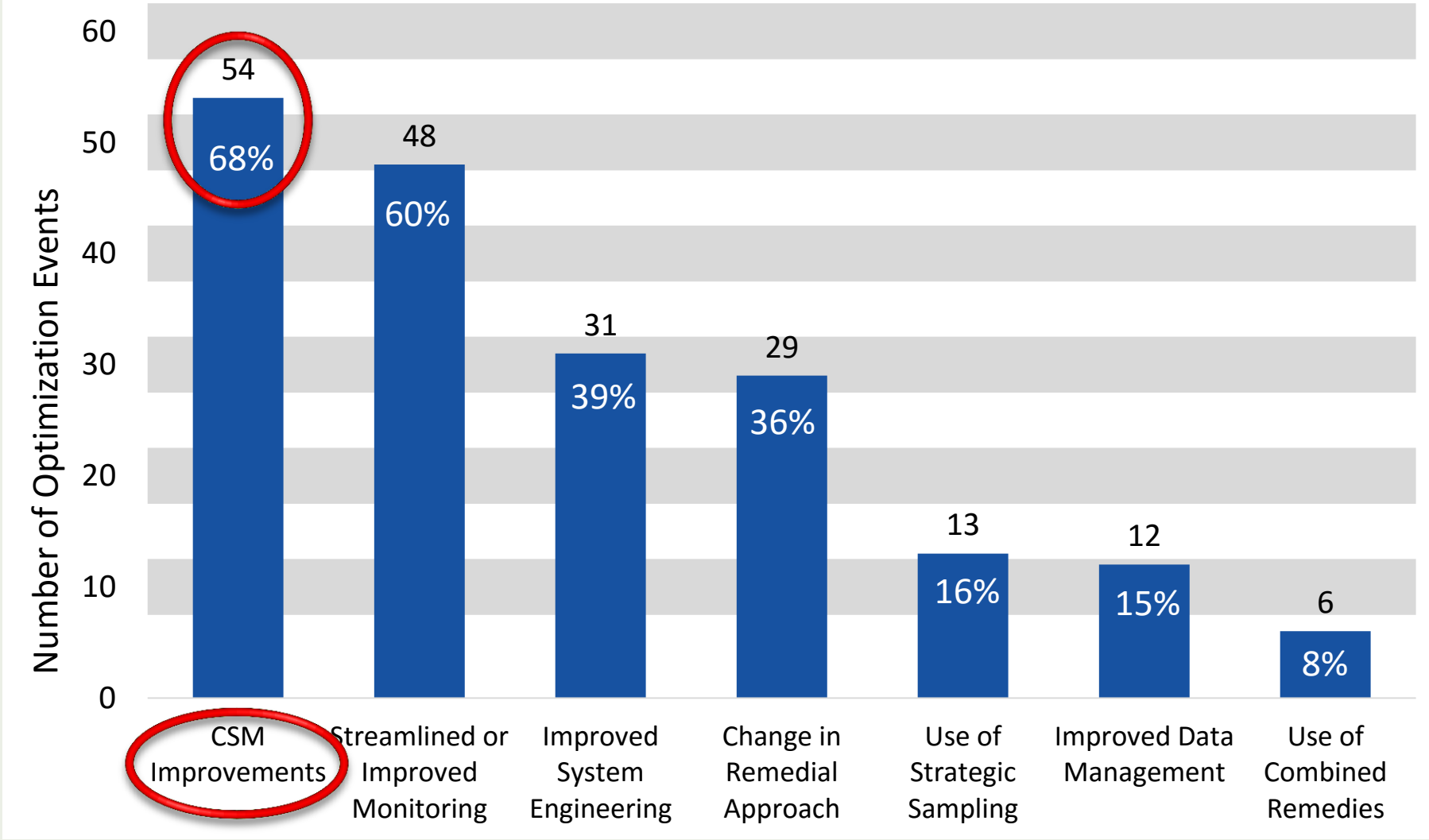
~80% of the plume mass-discharge occurs in ~10% of the cross-sectional area!

The Rise of In-Situ Remedies



- **1980's - Pump and treat 70-90% of remedies; few in-situ remedies**
- **2010's - Pump and treat <30% of remedies; in-situ remedies ~40-50%**

2011 – 2015 Superfund Optimization Results



How "Well" Do You Understand Your Site Conditions?

- **Technology used influences the understanding you develop**
- **The scale of measurement must be appropriate for the scale of the heterogeneity**
  - » Variability of hydraulic conductivity and other parameters
  - » Weak vertical & transverse dispersion
  - » Heterogeneous distribution of NAPL sources
- **Monitoring wells are not optimal investigation tools**
  - » Wells yield depth-integrated, flow-weighted average contaminant concentration data
  - » Can not discern small scale heterogeneities controlling contaminant transport & distribution in groundwater
- **Monitoring wells have life cycle costs**

Why HRSC?

- **Provides a defensible Conceptual Site Model (CSM):**
  - » Allows the correlation of discrete contaminant data with stratigraphic and lithologic data
  - » Identifies and delineates source zones
  - » Delineates plume cores and plume in three-dimensions
  - » Enables estimation of contaminant mass flux
    - › In both mobile and immobile porosity zones
- **Increases remedial efficiency**
  - » Reduces remedial footprint/targeted remedial volume
  - » Enables the evaluation of targeted in situ and ex situ remedies
- **Reduces project time frames**

Cost of Remedy vs. Cost of Characterization

- Remedies based on a flawed CSM may not perform as expected, increasing the time it takes to achieve clean-up, and the overall cost
- HRSC makes the investment upfront to obtain a more complete and realistic CSM
- Pay a little more now to avoid paying a lot more later
  - » Until the CSM reflects reality, investigation and cleanup will be costly – pay the costs upfront and get the CSM right to avoid paying more later

Return on Investigation!

What is HRSC ?

- **Subsurface investigation appropriate to the scale of heterogeneities in the subsurface which control contaminant distribution, fate and transport, and that provides the degree of detail needed to understand:**
  - Exposure pathways
  - Contaminant mass distribution and flux by phase and by geologic media (mobile and immobile)
  - Processes affecting fate of contaminants
  - How remedial measures will affect the problem

HRSC Addresses Two Critical Issues

- **Sampling Scale and Data Averaging**
  - » Measurements must be made at a scale that is meaningful with respect to the variability of the quantity being measured
- **Coverage**
  - » Enough measurements at the right locations
    - › Horizontal spacing
    - › Vertical spacing

How?

A set of methods or techniques found to be the most effective and practical means in achieving an objective while making the optimum use of resources

Triad!

Systematic Planning

A process for building a consensus vision for conducting environmental investigation and remediation

Dynamic Work Strategies

A work strategy that incorporates the flexibility to adapt to information generated by real-time measurement technologies

Real-Time Measurement Technologies

Real-time = within a timeframe that allows the project team to react to the information while in the field

How Is Triad Data Collection Different?

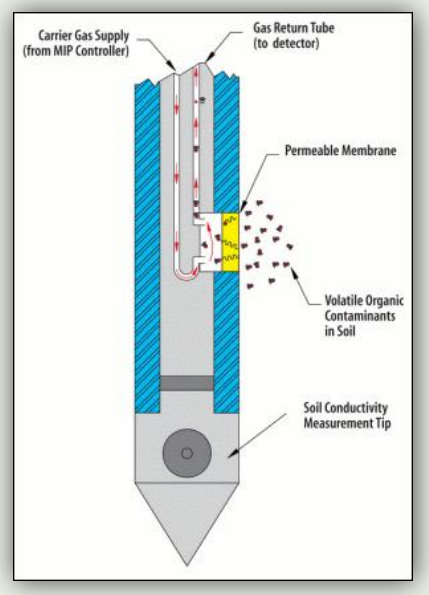
- Provides a greater density of measurements
- Uses collaborative data sets
- Employs strict field QA/QC
  - » Maximize usefulness of data
  - » Target collaborative sample analysis where needed
- Often uses field-based action levels or response factors with a margin of safety
- Uses real-time data management and communication strategies
  - » High volume of data gathered to capture, process, format for stakeholder decision-making

Complementary Toolsets

- **Direct-sensing technologies**
  - » High density of discrete measurements
  - » Determine spatial and matrix distribution of contaminants
- **Conventional tools**
  - » Optimally augment direct-sensing data
- **Real-time data interpretation**
  - » Build conceptual site model during field effort
- **Distance collaboration tools**
  - » Include stakeholders and decision makers in field decisions

Direct Sensing Tools

Rapidly capture essential characterization objectives



- **Contaminant sensors –**
  - » VOCs, PHCs/PAHs and metals
    - › Spatial distribution of contaminants
    - › Nature and extent
    - › Where to target/remediate
    - › Reduction of remedial volume/extent
- **Matrix sensors**
  - » Stratigraphy, hydraulic conductivity, electrical conductivity
    - › Geologic CSM
    - › Matrix distribution of contaminants
    - › Identify feasible technologies
    - › How to remediate

Conventional Tools

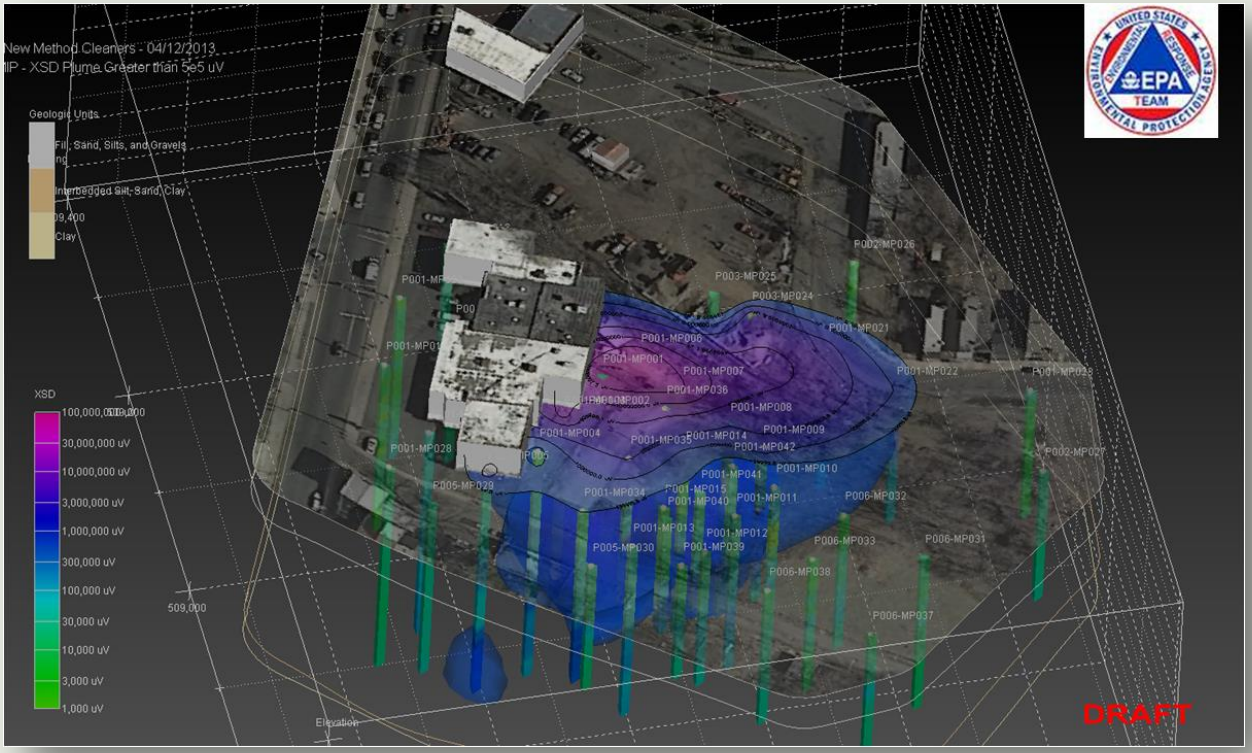
Optimally placed vapor points, borings, discrete samples, wells

- Quantify and verify direct-sensing information
- Fill specific data gaps

Real-Time Data Interpretation

Build and challenge the CSM in the field

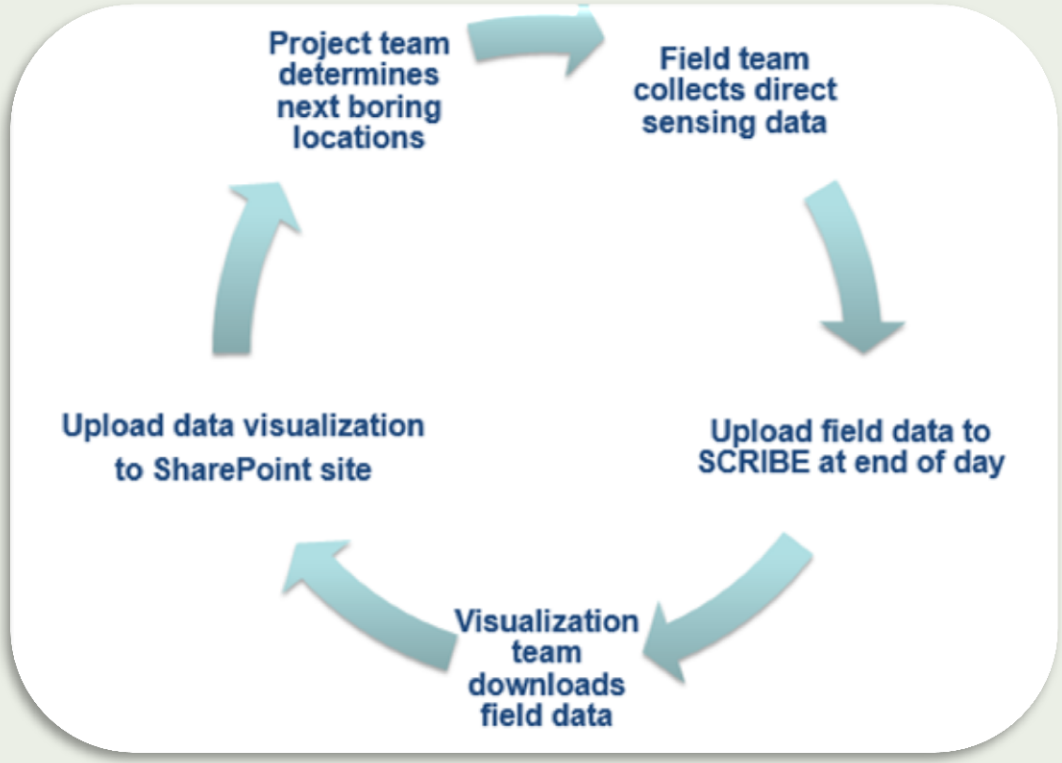
- Identify and fill data gaps
- Determine where to focus remediation
- Obtain information to determine feasible technologies



Data Management and Collaboration

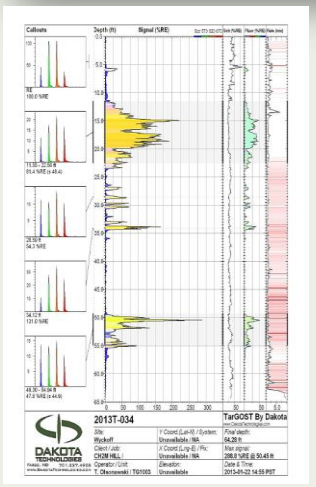
Capture, share, and evaluate data while team is in the field

- Involve all stakeholders/decision makers in the investigative process
- Develop interpretations individually with access to raw data
- Address unique stakeholder concerns
- Reach consensus on CSM and next actions



Tools for Obtaining Vertical Profiles in Unconsolidated

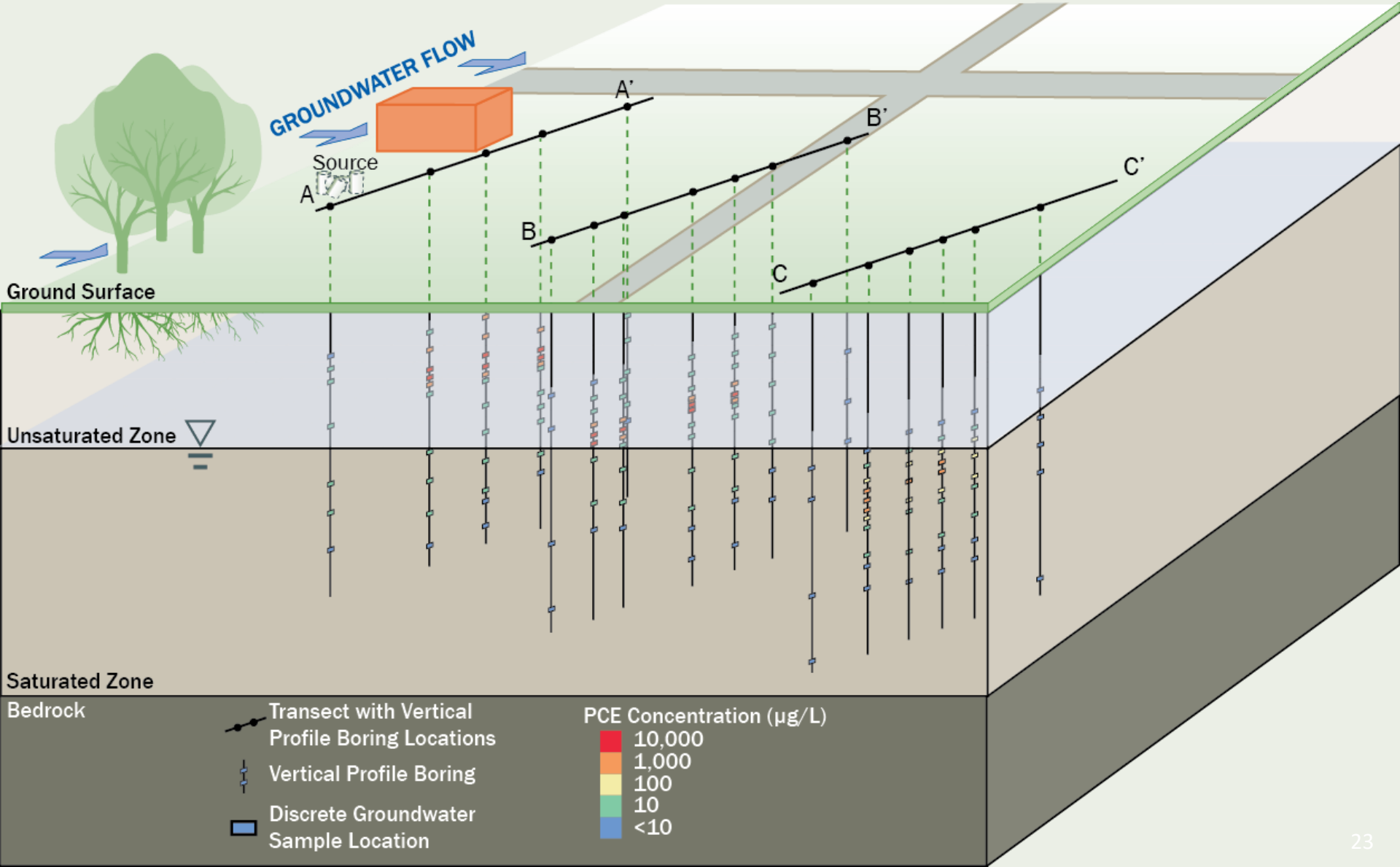
- **Qualitative contaminant data**
  - » MIP – LIF – PID – FID – Immunoassay – Colorimetric
- **Hydrostratigraphic measurements**
  - » Electrical conductivity meter – Cone penetrometer – Hydraulic Profiling Tool – Waterloo^{APS}
- **Direct push groundwater sampling**
  - » Various discrete/grab sample devices
- **Soil coring**
  - » Direct push – Sonic – Auger – Rotary
- **Quantitative contaminant data**
  - » Mobile laboratory – Fixed laboratory



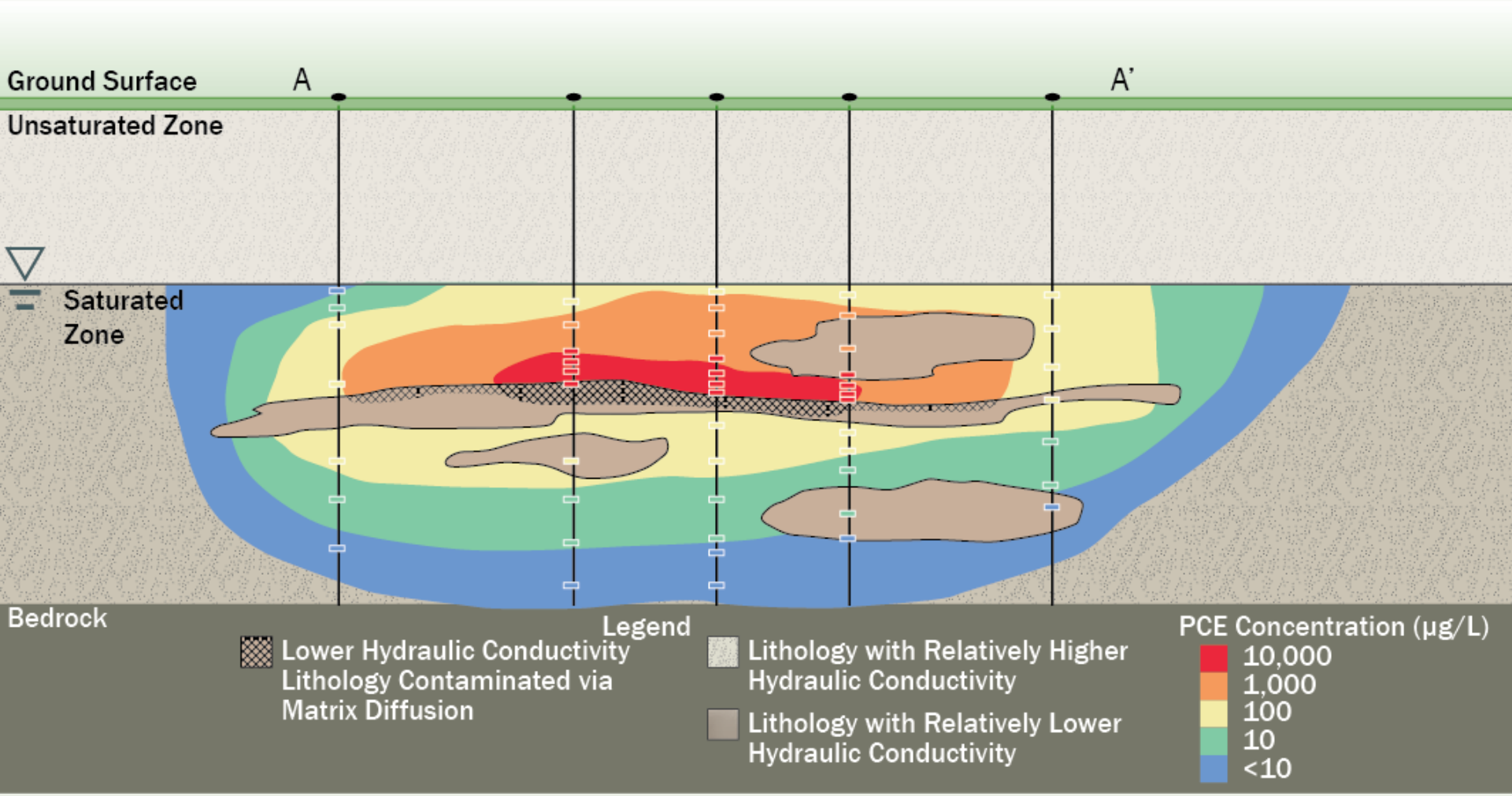
Tools for Obtaining Vertical Profiles in Fractured Media

- **Rock core measurements**
  - » Contaminant analysis with microwave assisted extraction – Physical, mineralogical and microbial measurements – Degradation microcosms
- **Open hole measurements** (time during which boreholes are open should be minimized)
  - » Geophysics – Temperature – Flow metering – Packer testing – Discrete groundwater sampling
- **Lined hole measurements**
  - » Geophysics – Temperature – Transmissivity profiling – Multilevel groundwater sampling

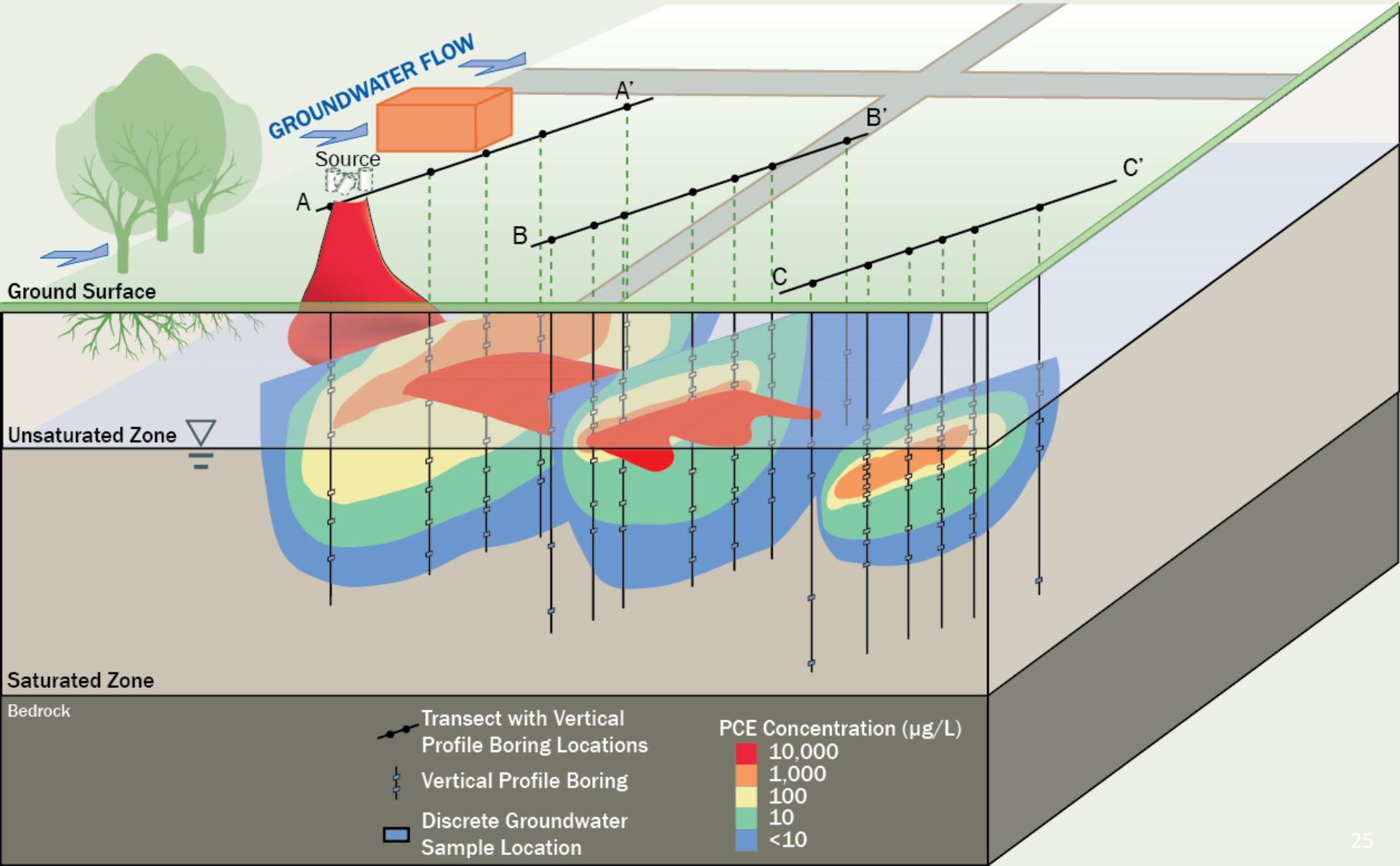
Multiple Vertical Profiles along Transects



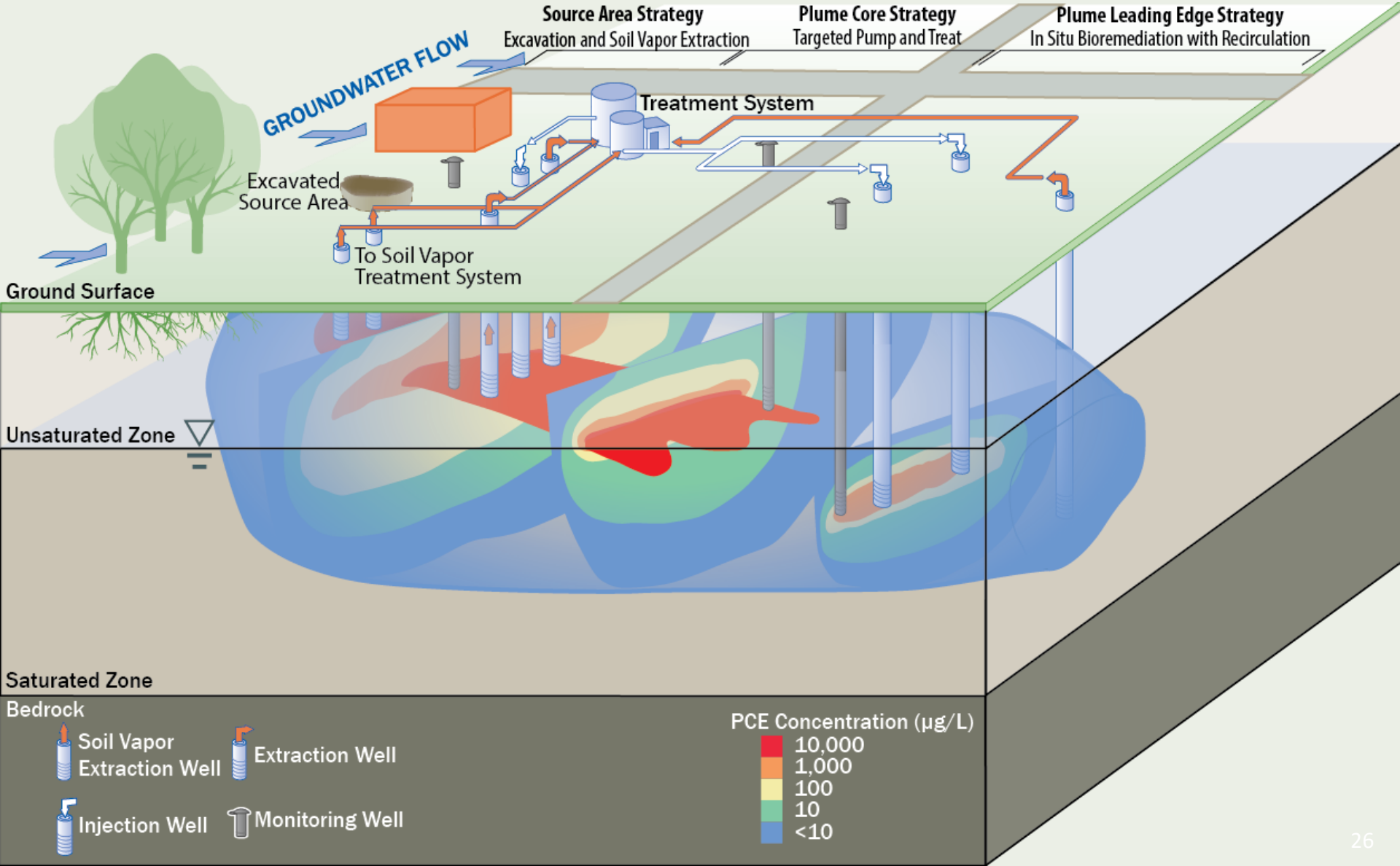
Transect A – A’


Ground Surface
A
A’
Unsaturated Zone
Saturated Zone
Bedrock
Legend
Lower Hydraulic Conductivity Lithology Contaminated via Matrix Diffusion
Lithology with Relatively Higher Hydraulic Conductivity
Lithology with Relatively Lower Hydraulic Conductivity
PCE Concentration (µg/L)
10,000
1,000
100
10
<10

Multiple Vertical Profiles along Transects



Combined Targeted Remedies



The HRSC Toolbox Approach

- **Triad & HRSC**
  - » Systematic Project Planning
  - » Dynamic Work Plans
  - » Real-time Measurement Tools
  - » Multiple vertical profiles along transects
  - » High density data
  - » Manage uncertainty

- **Complementary toolsets**
  - » Direct sensing
  - » Geophysics
  - » Conventional approaches
- **Collaborative datasets**
  - » Contaminant 3D distribution
  - » Hydrostratigraphic units
  - » Geologic CSM
- **Multiple lines of evidence**

HRSC Review

- **Why?**
  - Realistic CSM
  - Better defined contaminant mass distribution
  - Targeted and more efficient remedies
- **What?**
  - A methodology for understanding and properly accounting for the affects of subsurface heterogeneity
  - Uses scale-appropriate measurements and sample spacings that are consistent with the scale of variability of the property being measured
- **How?**
  - Transect-based vertical profiling planned and implemented using the Triad approach

Questions?